nature climate change

PERSPECTIVE

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Communication of the role of natural variability in future North American climate

Clara Deser[1]*, Reto Knutti[2], Susan Solomon[3] and Adam S. Phillips[1]

THE POTENTIAL TO NARROW UNCERTAINTY IN REGIONAL CLIMATE PREDICTIONS

BY ED HAWKINS AND ROWAN SUTTON

Erin Dagg & Samantha Wills

August 28, 2014

ATS 780

Applications

Big Picture

- Climate change impacts people, economy, and ecosystems
- Policy makers require *quantitative* climate prediction for planning and project funding
- Predictions of regional changes compared to global changes are more relevant to decision makers

Scientific Improvement

- Attempting to narrow uncertainty in future climate predictions through models
- Assessing the importance of natural variability and its uncertainty
  - Challenge is to better explain where, how, and how much natural climate variability may obscure anthropogenic climate change
- Costs of various degrees of adaptation

Hawkins and Sutton [2009], Deser et al. [2012a]

Sources of Uncertainty

Internal variability of the climate system

-Natural fluctuations that arise in the absence of any external forcing
-Can act to enhance or detract from anthropogenic climate change
-Examples: Pacific Decadal Oscillation, ENSO, etc.

Model (response) uncertainty

-Different models yield difference responses to same forcing
-Examples: differences in physical and numerical formulations

Scenario (forcing) uncertainty

-Uncertainty of external factors that influence the climate system
-Examples: anthropogenic GHGs, stratospheric ozone, land use change, etc.

Hawkins and Sutton [2009]; Deser et al. [2012a]; Deser et al. [2014]

Key Variables

- Three variables analyzed:
  - Surface Air Temperature (all papers)
  - Precipitation (Deser et al. [2012a,b], Hawkins and Sutton [2011])
  - Sea Level Pressure (Deser et al. [2012b, 2014])

- Temperature is the main focus
  - Deser et al. [2012b] study showed that the response to anthropogenic forcing is more detectable in surface temperature than in precipitation or atmospheric circulation (SLP)

- Precipitation results are considered
  - Deser et al [2014a] noted the effect of natural variability on future precipitation projections

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Model Setup

- CMIP3 -15 global climate models (GCM)
- 3 emission scenarios per GCM
  - SRES A1B, A2, and B1
  - 2000 - 2100 time frame
- 1 realization per scenario; thus, 45 total predictions

- Separated three components of uncertainty
  - Internal Variability
  - Model Uncertainty
  - Scenario Uncertainty

  *No interactions between 3 sources of uncertainty

$$\boxed{T(t) = V + S(t) + M(t)}$$

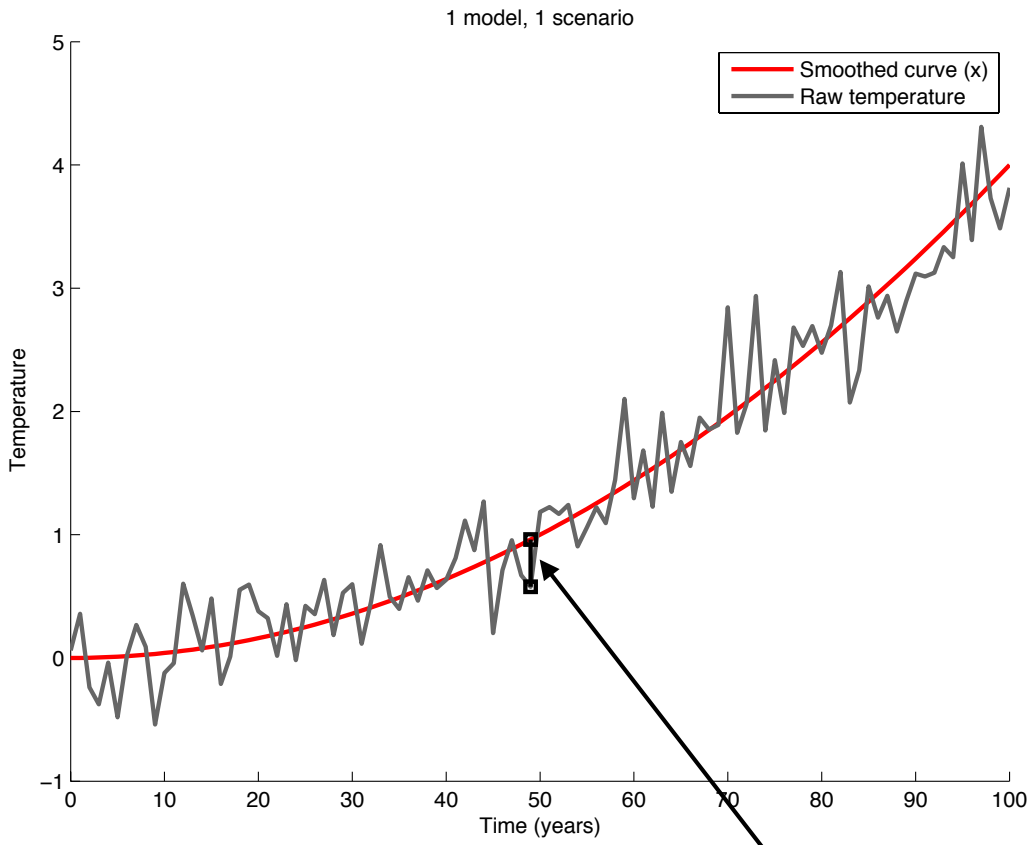
Total variance

Model Uncertainty

Internal Variability

Scenario Uncertainty

Defining Internal Variability



$$X_{m,s,t} = x_{m,s,t} + i_{m,s} + \varepsilon_{m,s,t}$$

raw predictions

smooth fit

reference temperature

residual (internal variability)

Internal Variability →

$$V = \sum_m W_m \, \mathrm{var}_{s,t}(\varepsilon_{m,s,t})$$

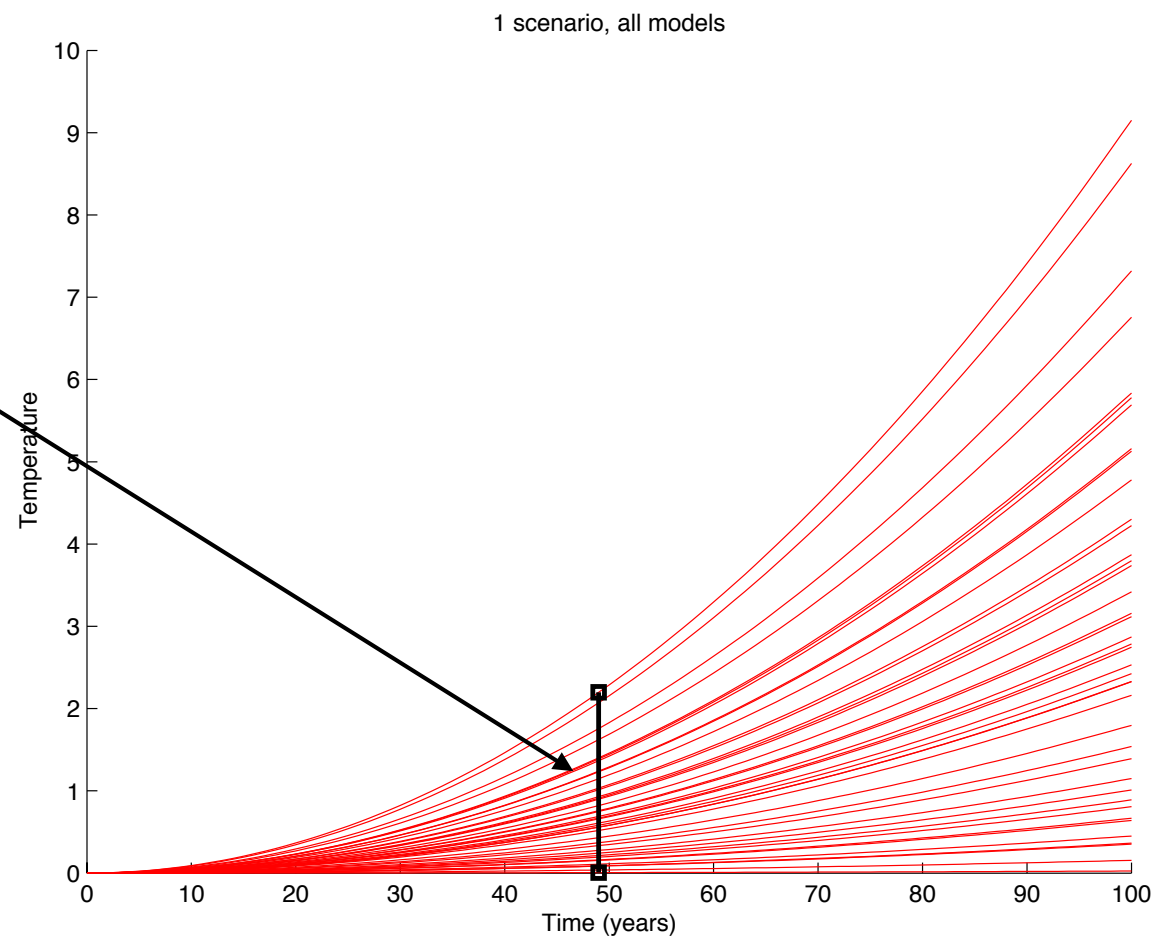
*Difference between the raw data and the smoothed curve

Defining Model Uncertainty

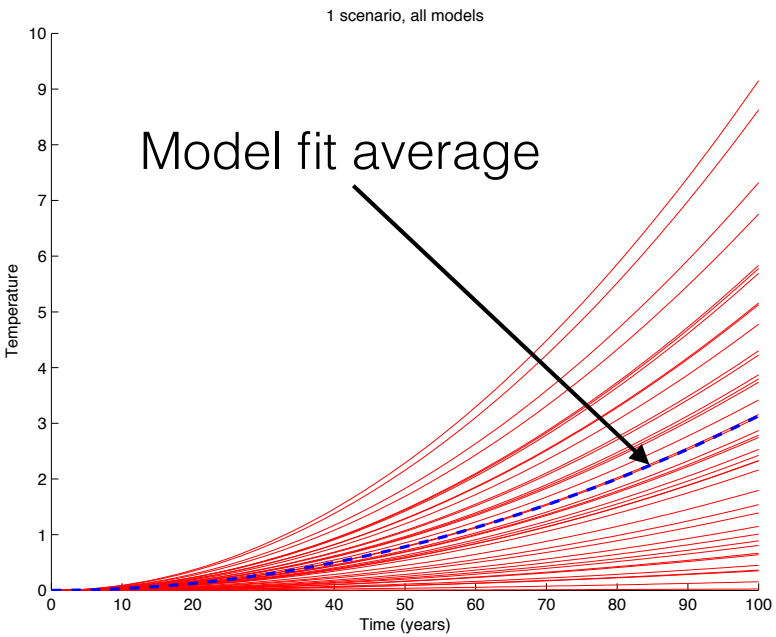
Model Uncertainty

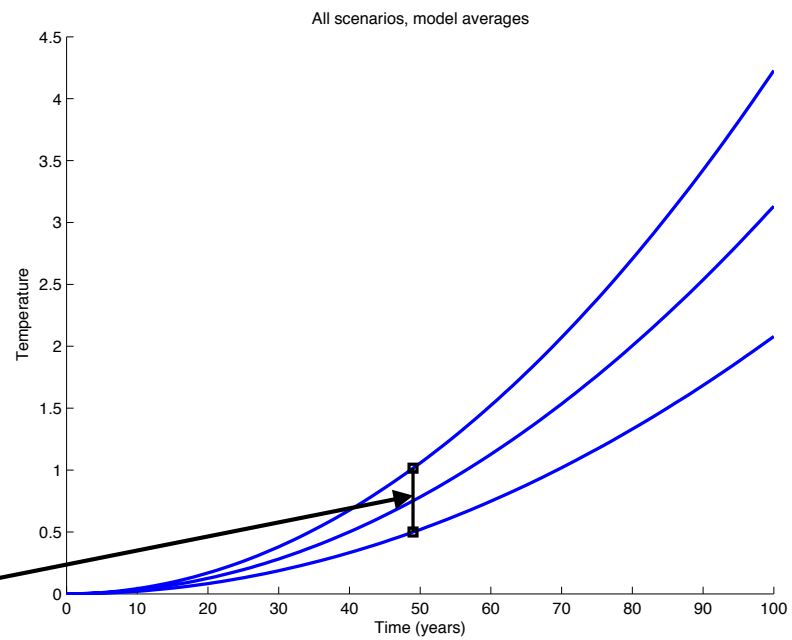
*Spread between the model fits

$$M(t) = \frac{1}{N_s} \sum_s \mathrm{var}_m^W (x_{m,s,t})$$



Defining Scenario Uncertainty





Scenario Uncertainty

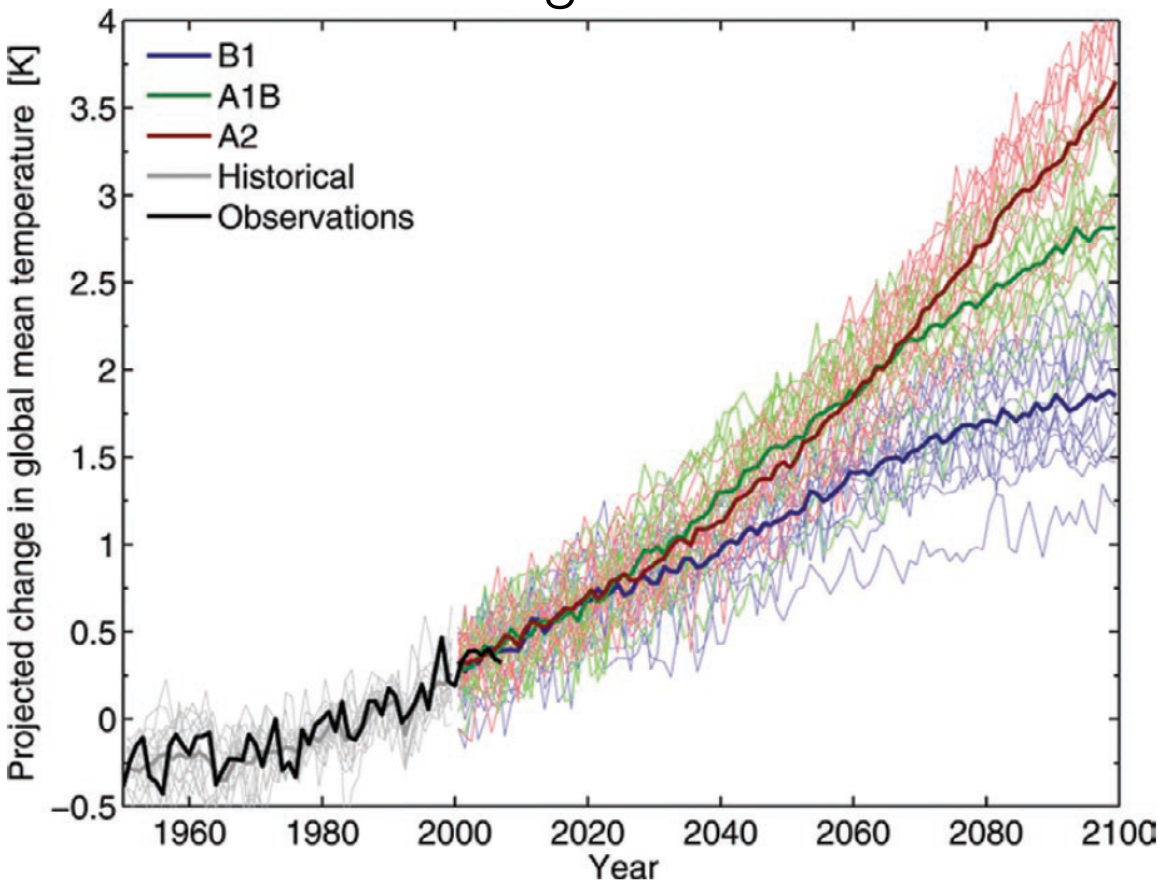
*Spread between model average for each scenario

$$S(t) = \mathrm{var}_s\left(\sum_m W_m x_{m,s,t}\right)$$

*Note: only taking variance between three data points…

Emissions Scenarios

Figure 1

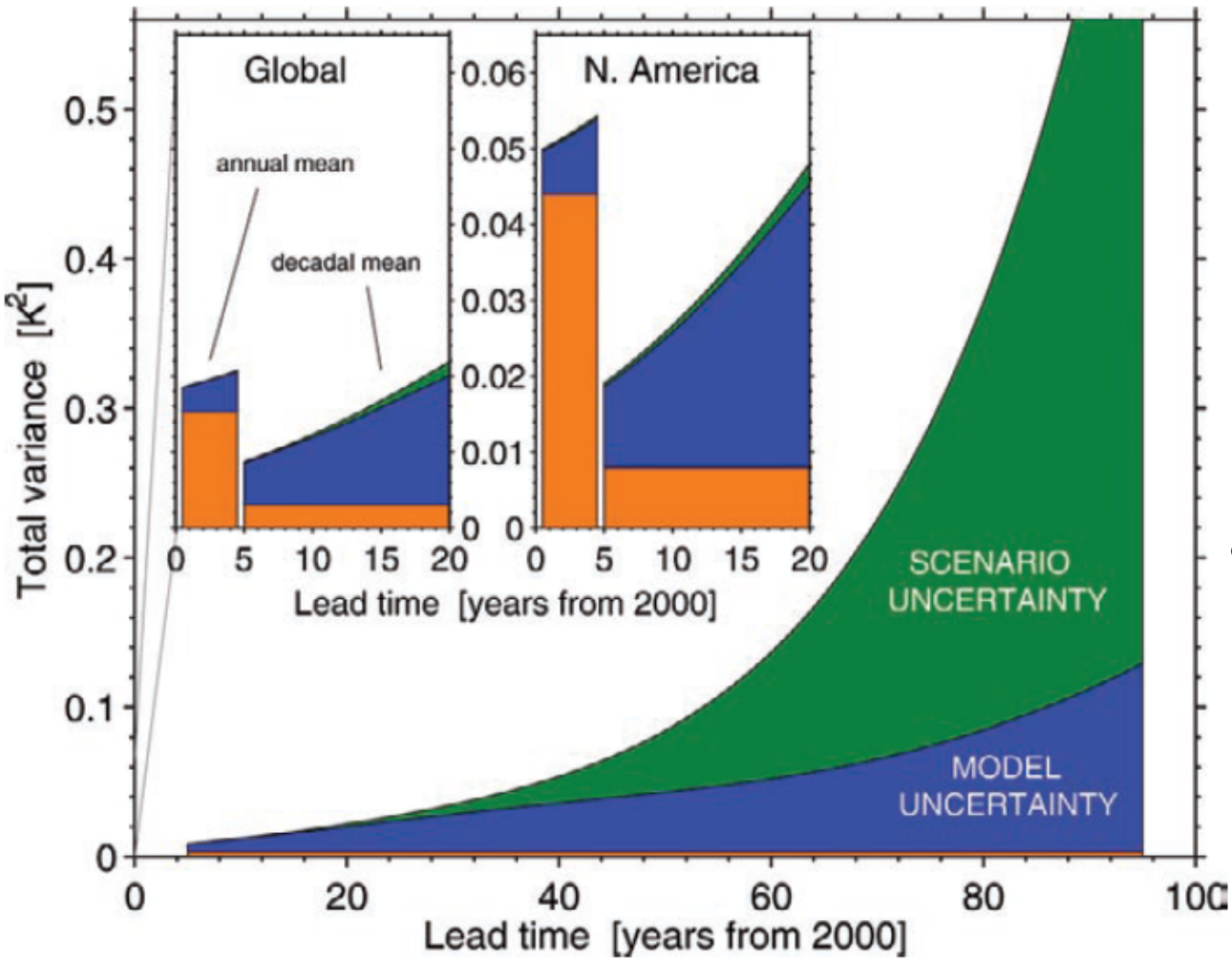


- Temperature predictions based on three emissions scenarios
- “Delayed effect” evident in agreement up to 2025
- Each of the 15 GCMs have different responses to the same forcings

Hawkins and Sutton [2009]

Relative Importance

Figure 2



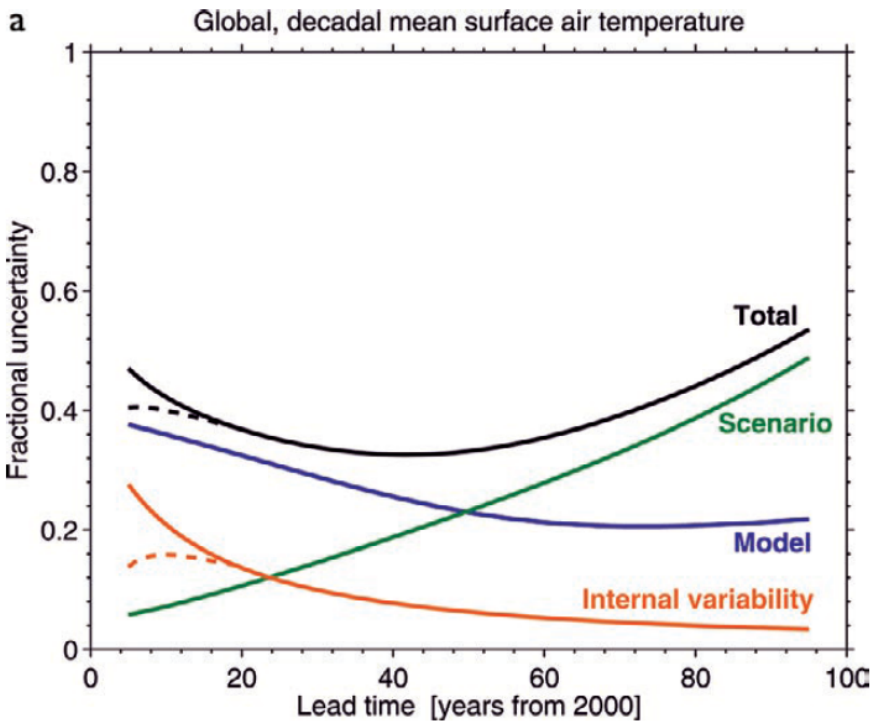
Hawkins and Sutton [2009]

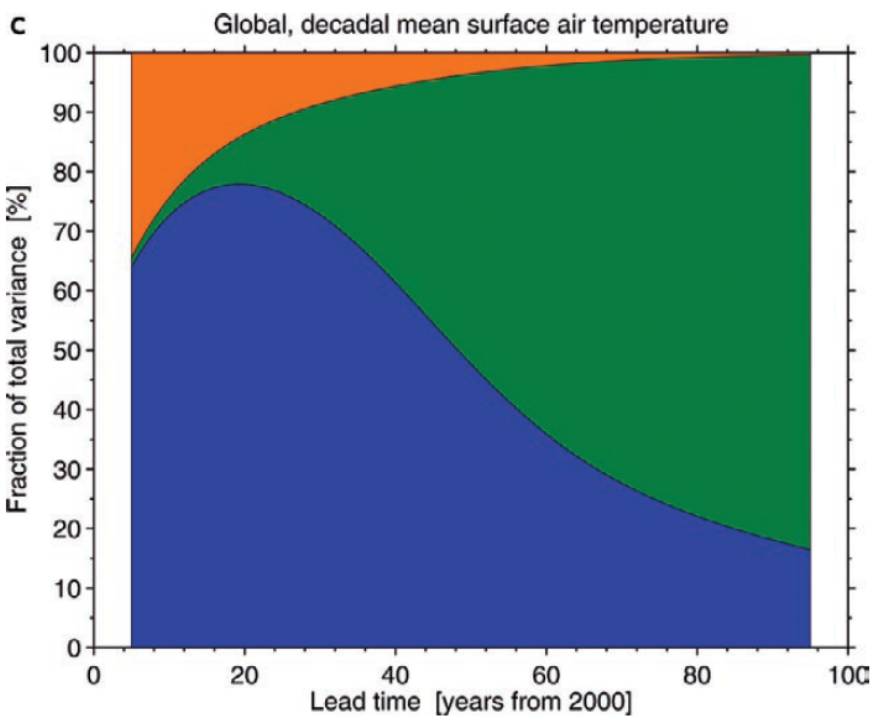
Uncertainty varies with:

- Prediction lead time
- Spatial scale
- Temporal averaging scale

- Internal variability is:
  - constant at all times
  - more important at shorter timescales and smaller spatial scales

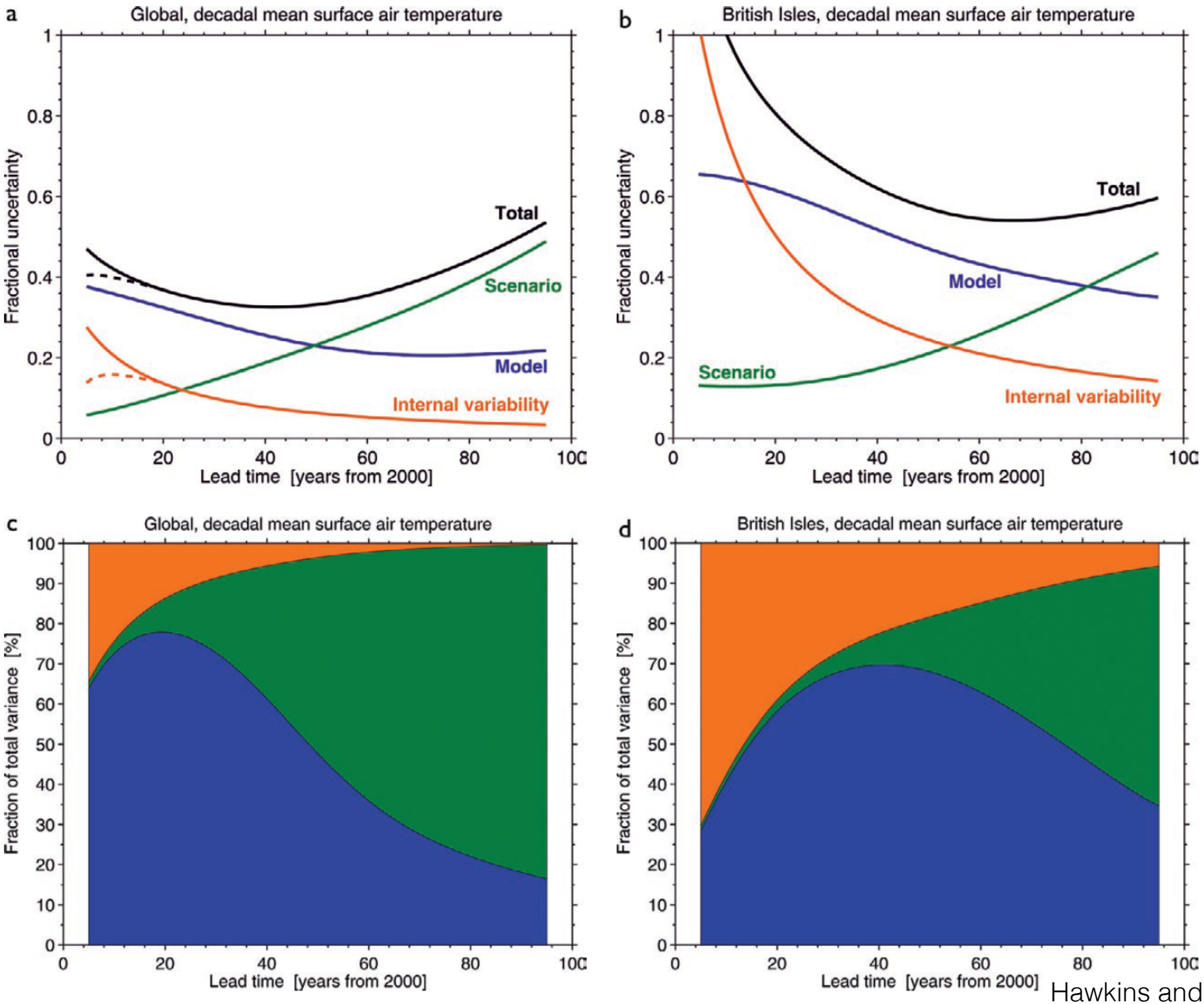
Figure 4





- Fractional Uncertainty
  - Prediction uncertainty divided by the expected mean change (σ/μ)
  - Importance of each source of uncertainty
  - Reciprocal of "signal-to-noise" ratio
- Fraction of Total Variance
  - Relative importance of each source of uncertainty
  - How much each source matters at a given time compared to the total uncertainty
- Recall…
  - Internal variability is constant
  - Total uncertainty is increasing at longer lead time

Hawkins and Sutton [2009]



Hawkins and Sutton [2009]

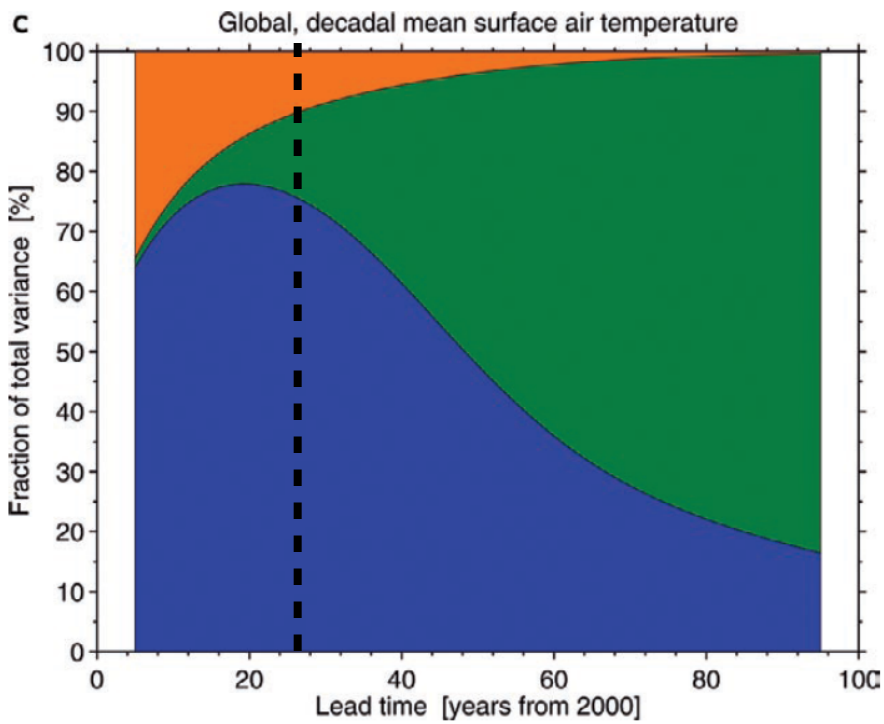
Fig. 4 Comments

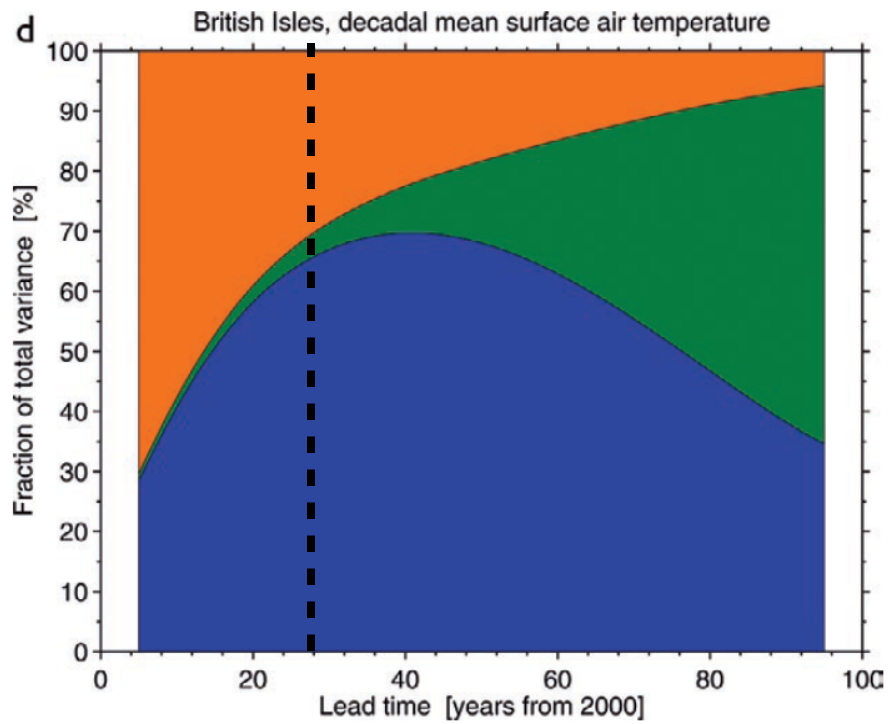
Dislike

- Hard to isolate importance at one time step
- "Relative" contribution may appear to be more important than it is

Like

- Effectively illustrates spatial dependence
- Provided a link to other area examples





Hawkins and Sutton [2009]

More goodies...

Area and Location

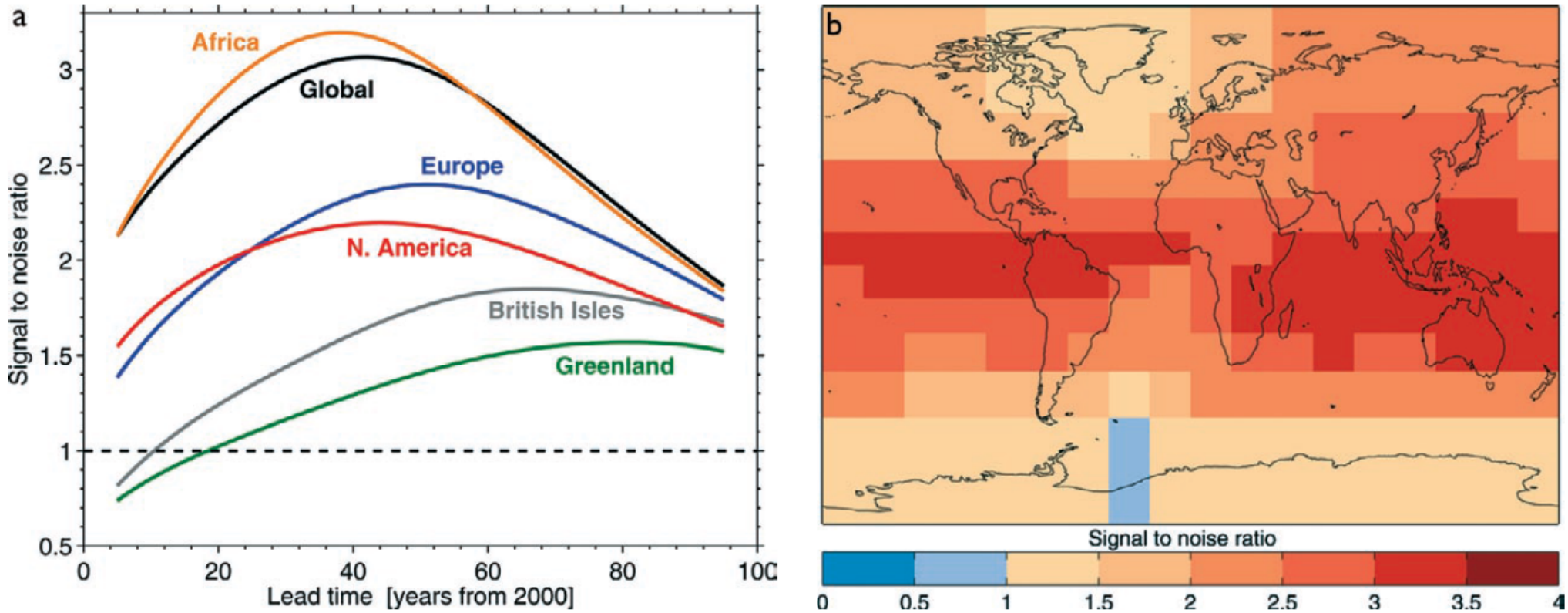
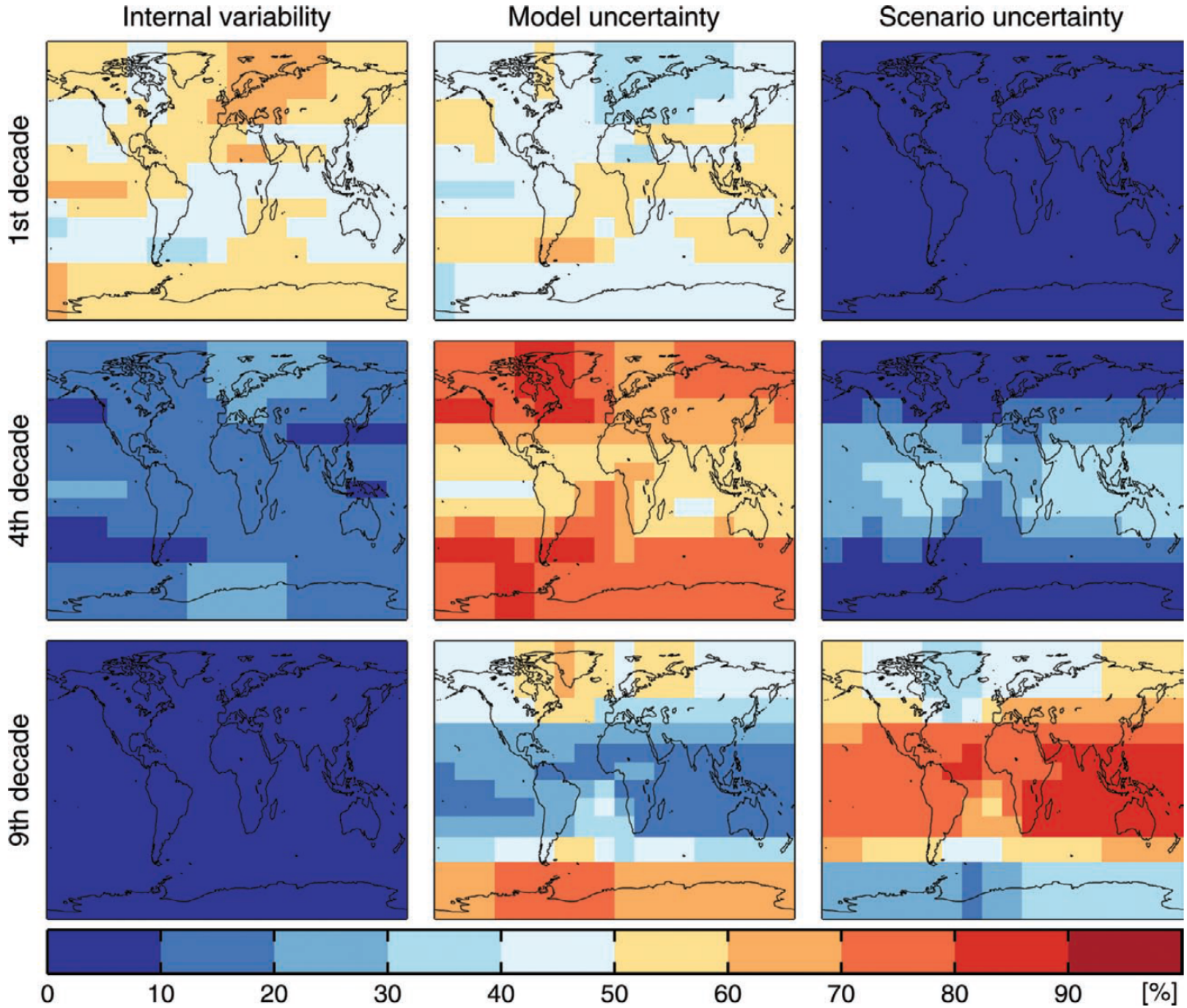


Figure 5

- Latitudinal dependence matters along with spatial scale
- Maximum in signal-to-noise corresponds to minimum in uncertainty
- Maximum generally shifts to longer lead times for higher latitudes

Hawkins and Sutton [2009]

Sources of uncertainty for various lead times and their relative importance



Hawkins and Sutton [2009]

Figure 6

Main Points

- Model uncertainty matters most
  - Potential to decrease uncertainty in climate predictions with **model improvement**

- More **economical** to invest in climate science progress vs. adaptation to a changing climate in future years

- Internal variability only matters on a scale of 1-2 decades
  - Model uncertainty and internal variability dominate on **shorter timescales**
  - Model and scenario uncertainty dominate on longer timescales

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Model Setup

- NCAR Community Climate System Model v3 (CCSM3)
  - 40 member ensemble
  - Same external forcing
    - A1B emission scenario
    - 2000 - 2060 time frame

- Slightly different atmospheric initial conditions for each run, where each realization is treated with equal weight

- "Because all simulations are performed with the same model and are identical until 2000, twenty-first century differences cannot be ascribed to model errors, biases or initialization shocks."

Deser et al. [2012a]

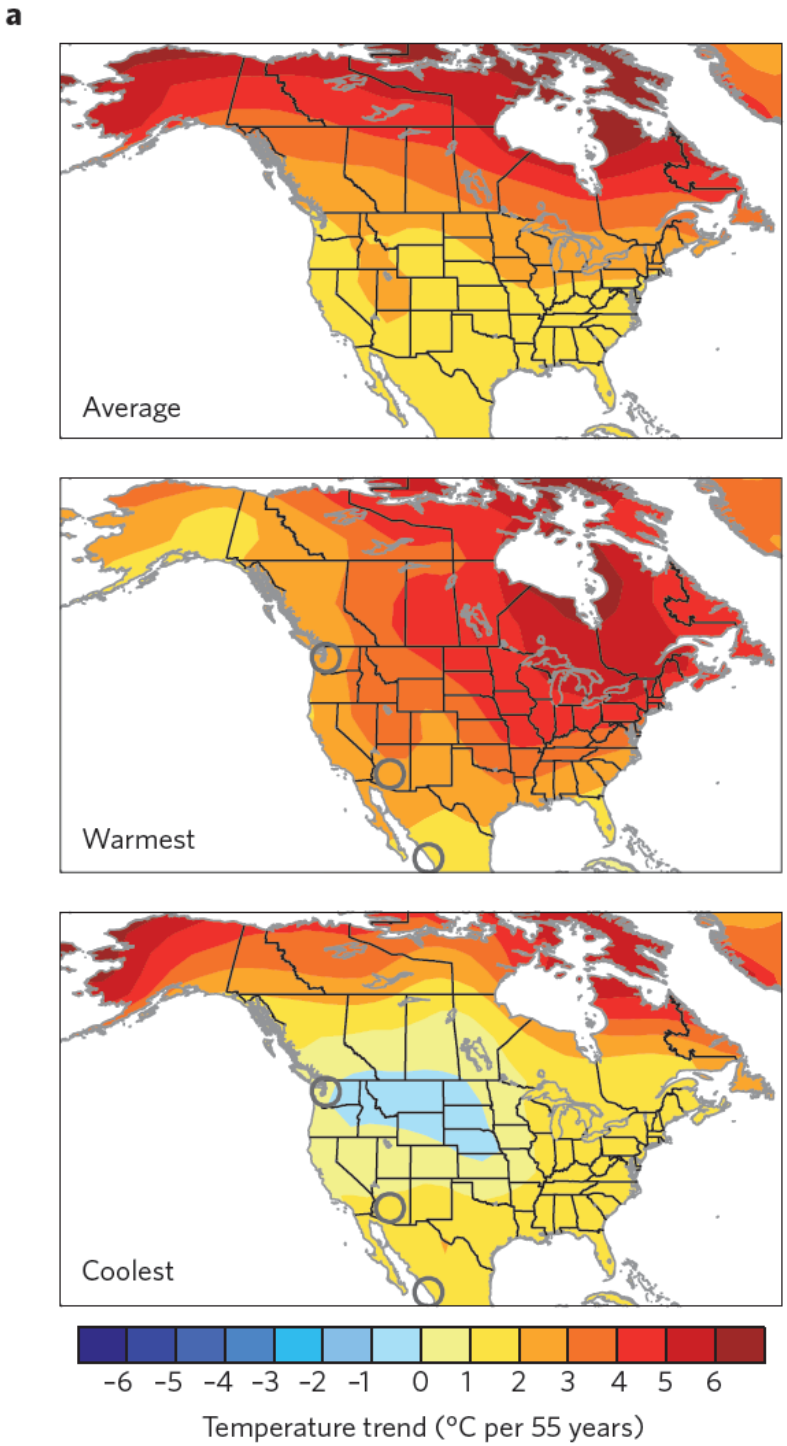


Figure 1

- Depicting projected temperature changes for DJF season over the next 55 years
- Top panel is the average of the 40 members
- Evident that the two extrema are different from the ensemble average
- Deser et al. [2012a] attribute differences in the model runs to internal variability

Deser et al. [2012a]

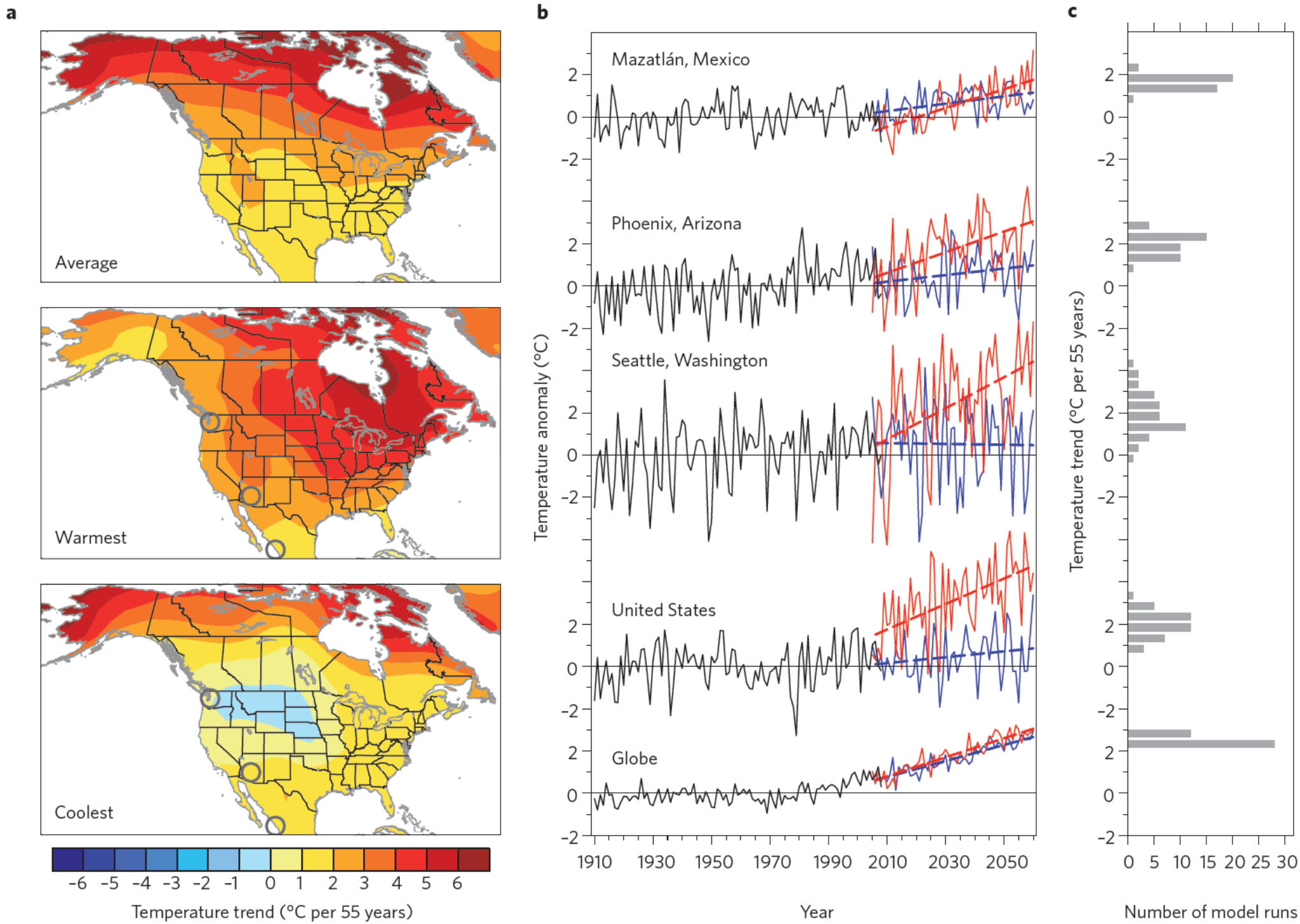
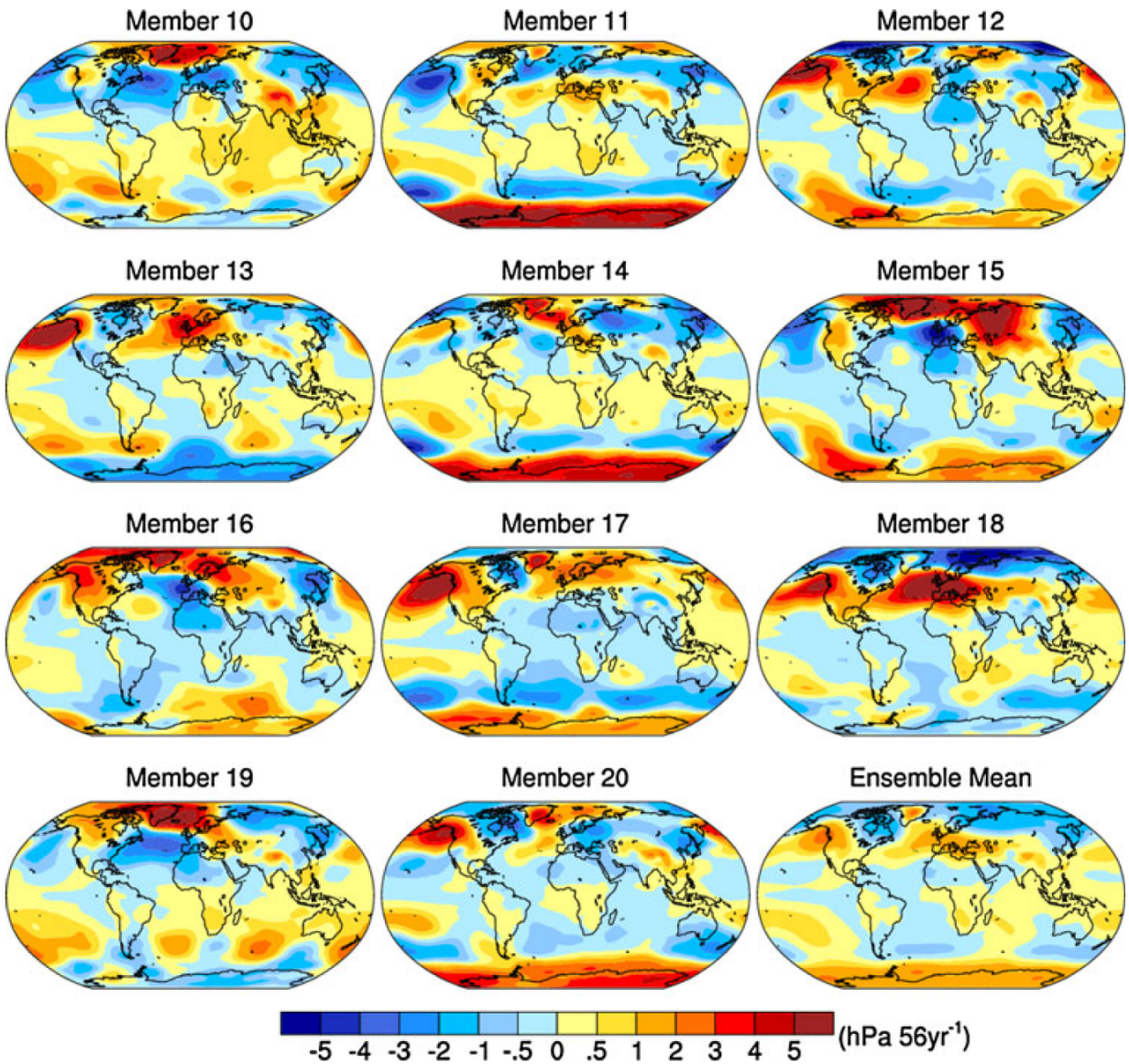


Figure 1

Deser et al. [2012a]

Comments on MMM

Spatial trends in SLP among multiple model runs



- Using ensemble maps:
  - illustrates model spread
  - highlights difference between individual member and ensemble mean
  - sometimes provides an overwhelming amount of information
- Bar graphs:
  - are a more compact way to convey the model spread
  - provide a quantitative analysis

Deser et al. [2012b]

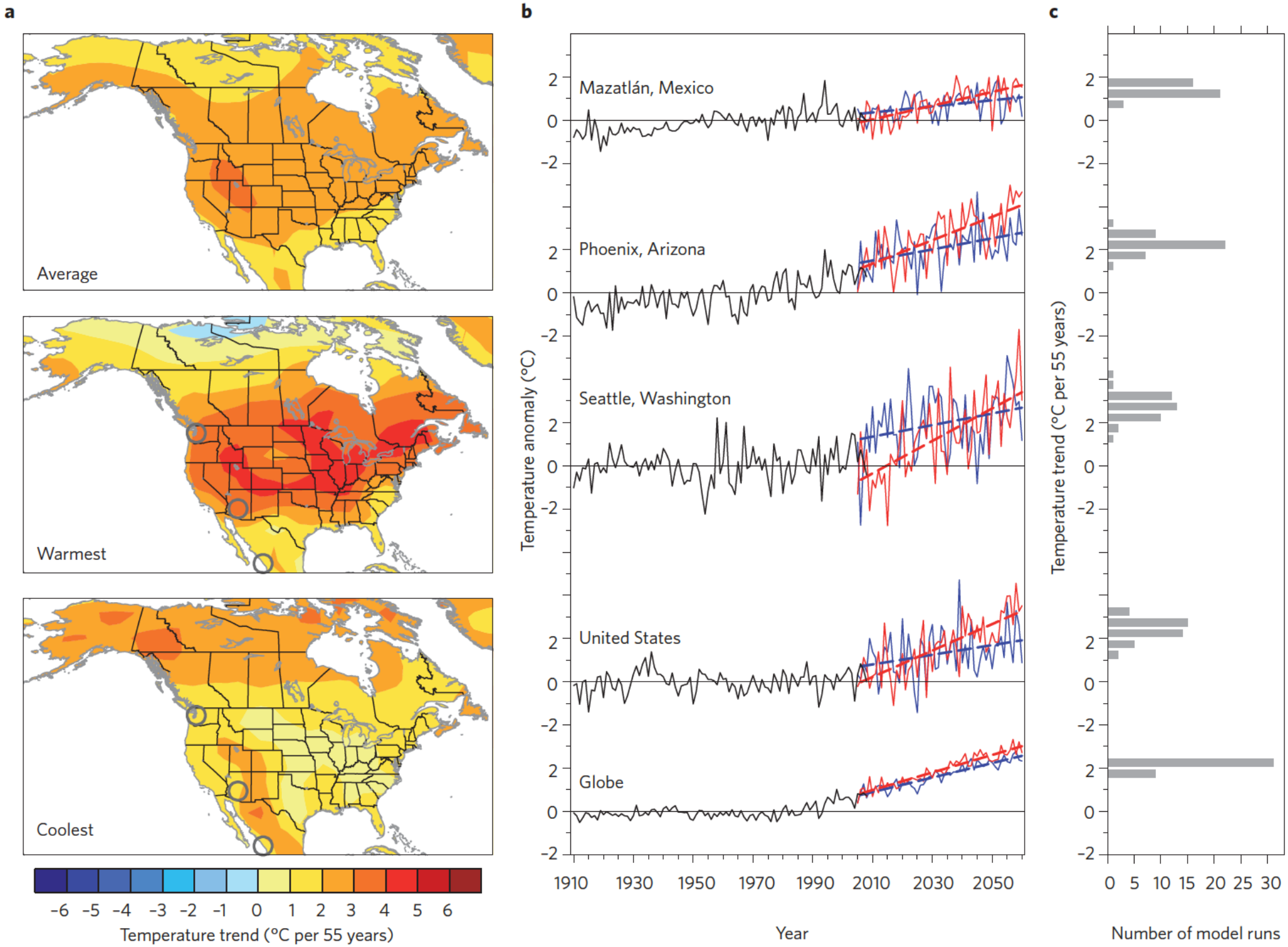


Figure 2: Projected temperature changes for JJA season

Deser et al. [2012a]

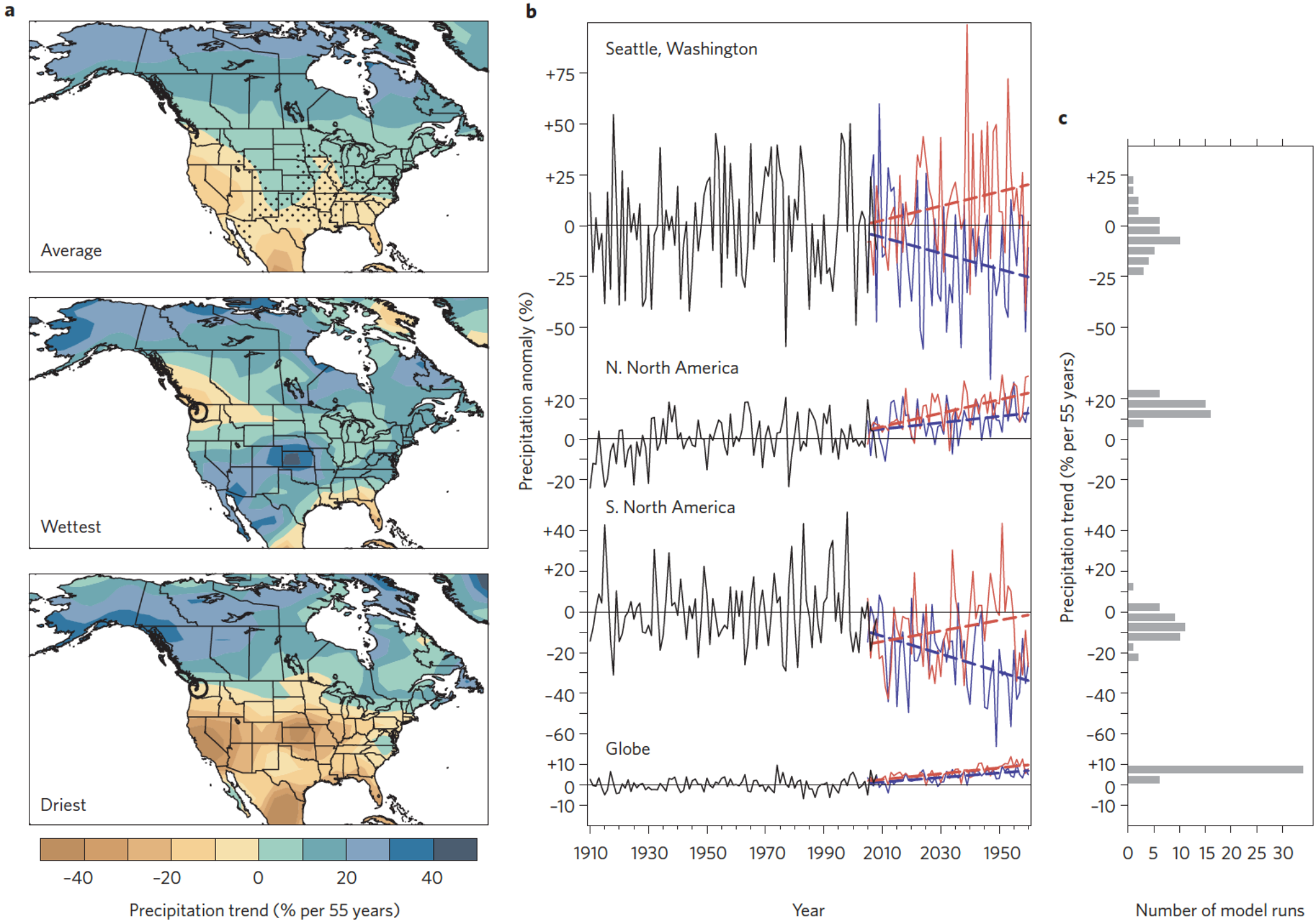


Figure 3: Projected precipitation changes for DJF season

Deser et al. [2012a]

Main Points

- Internal variability matters over periods as long as 50 years
  - Not limited to interannual-to-decadal timescales
  - Need to equally consider each member prediction
  - Important to consider a range of adaptation strategies
- Model improvement will be unable to fully resolve uncertainty due to the presence of internal variability
  - Differences are largely a consequence of the chaotic nature of large-scale atmospheric circulation patterns
- Notes spatial and latitudinal dependence on internal variability
  - Will be more difficult to predict changes at higher latitudes (e.g. Seattle v. Mazatlán, Mexico)

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Spatial Scale and Location

Similarities

- Internal variability is a more dominant factor on smaller spatial and shorter temporal scales
- Uncertainty due to internal variability increases poleward
  - Deser et al. [2012a] notes more agreement in model runs for Mazatlán, Mexico compared to Seattle, WA
  - Hawkins and Sutton [2009] notes lower signal-to-noise ratios as you approach the poles

Differences

- Deser et al. [2012a] focuses on North America
  - Provides examples of cities and hemispheric regions
- Hawkins and Sutton [2009] focuses on the globe and the British Isles
  - Provides examples of continents and supplies a link for additional regions

Key Modes of Uncertainty

Deser et al. [2012a]

- Main focus is internal variability
- Believes internal variability matters on timescales of 50 years or longer
- Cautions that decisions should be weighed with internal variability in mind
- Mentions that some uncertainty will never be resolved

Hawkins and Sutton [2009]

- Focuses on all three sources of uncertainty
- Believes internal variability only matters 1-2 decades into the future
- Notes that scenario uncertainty exceeds internal variability at longer lead times
- Concluded that model uncertainty is worth further funding for improvement

Difference in Methods

Deser et al [2012a]

- Isolates internal variability by:
  - Eliminating model uncertainty by using the same model for all runs
  - Eliminating scenario uncertainty by forcing with the A1B scenario only
  - Analyzing the differences between the model runs

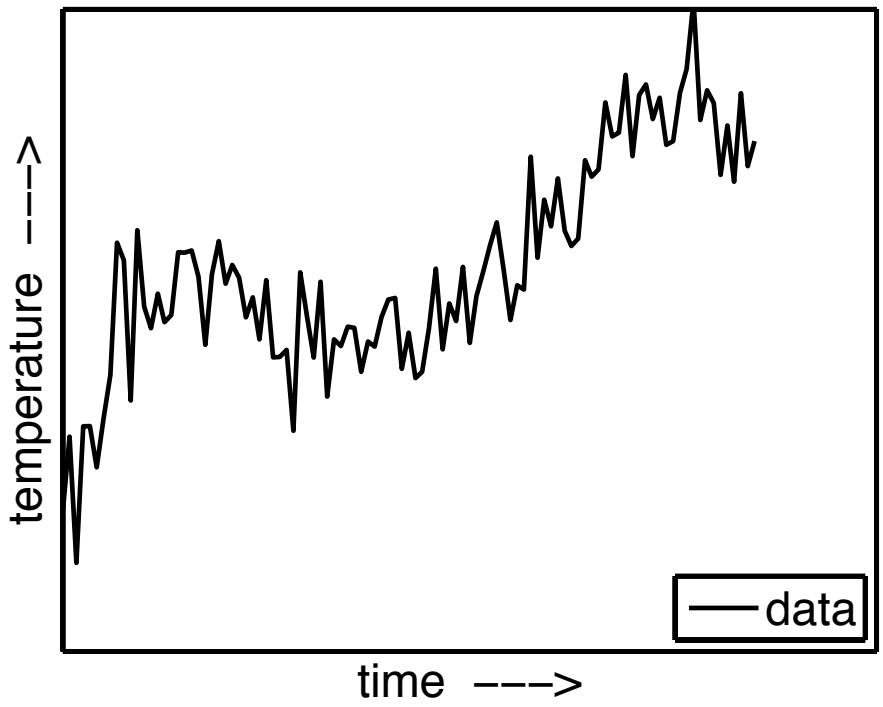
Hawkins and Sutton [2009]

- Separates uncertainty into its three sources by:
  - Calculating a constant value for internal variability
  - Calculating the model spread from the smooth fits
  - Calculating scenario uncertainty from average model fit

**Questionable how independent each uncertainty is…*

Difference in Methods

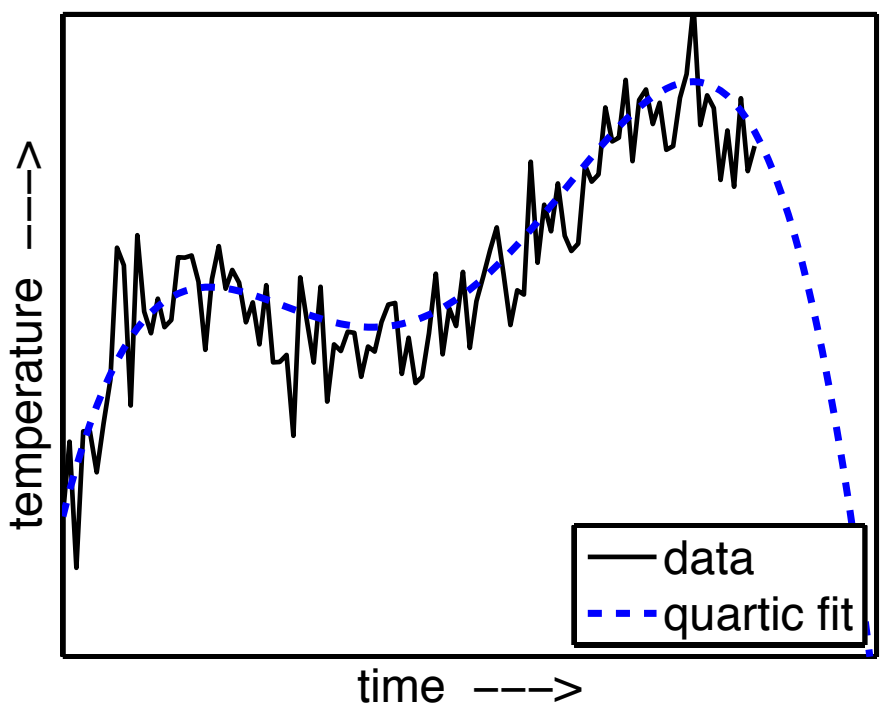
Hawkins and Sutton [2009]: Polynomial Fit



Each individual prediction was fit with a 4th-order polynomial over the years 1950-2099.

Difference in Methods

Hawkins and Sutton [2009]: Polynomial Fit



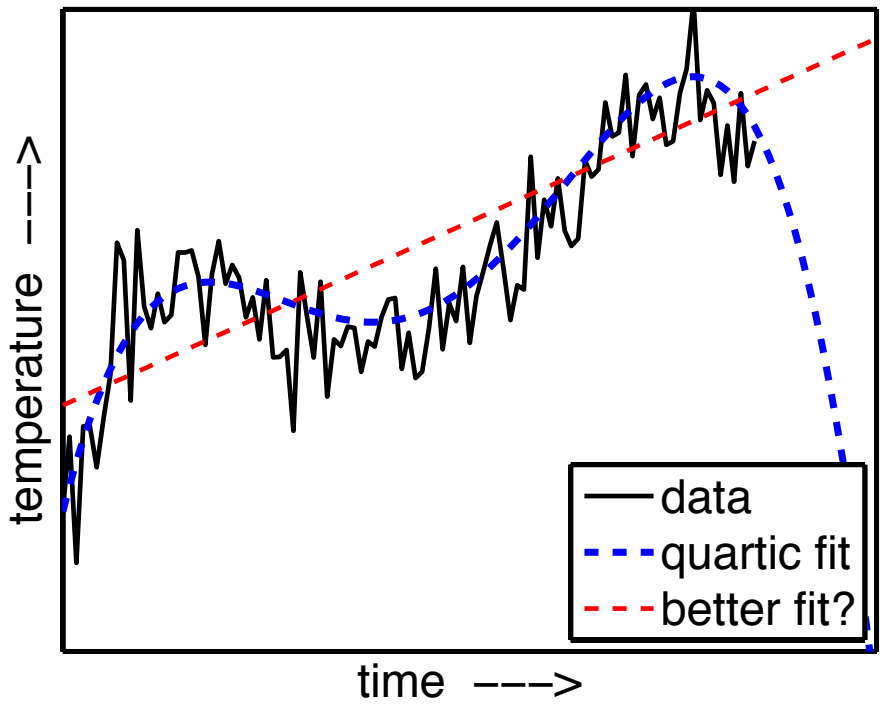
Each individual prediction was fit with a 4th-order polynomial over the years 1950-2099.

4th order polynomial

$$f(x) = ax^4 + bx^3 + cx^2 + dx + e$$

Difference in Methods

Hawkins and Sutton [2009]: Polynomial Fit



Deser et al. [2014] criticism:

- "With this definition, they effectively eliminated internal climate fluctuations with time scales longer than a few decades."
- "Thus, they were unable to assess the full contribution of internal variability to uncertainty in regional climate projections over the next 50 yr."

Food for Thought

Which is a more economical decision:
model improvement or adaptation planning?

How can you reduce internal variability…is it possible?

How do ethics play into regional climate predictions?

References

Deser, C., R. Knutti, S. Solomon, A.S. Phillips, 2012a: Communication of the role of natural variability in future North American climate. *Nature*, **2**, 775 - 779.

——, A. Phillips, V. Bourdette, H. Teng, 2012b: Uncertainty in climate change projections: the role of internal variability. *Clim Dyn.*, **38**, 527 - 546.

——, A.S. Phillips, M.A. Alexander, B.V. Smoliak, 2014: Projecting North American Climate over the Next 50 Years: Uncertainty due to Internal Variability. *J. Climate,* **27**, 2271 - 2296.

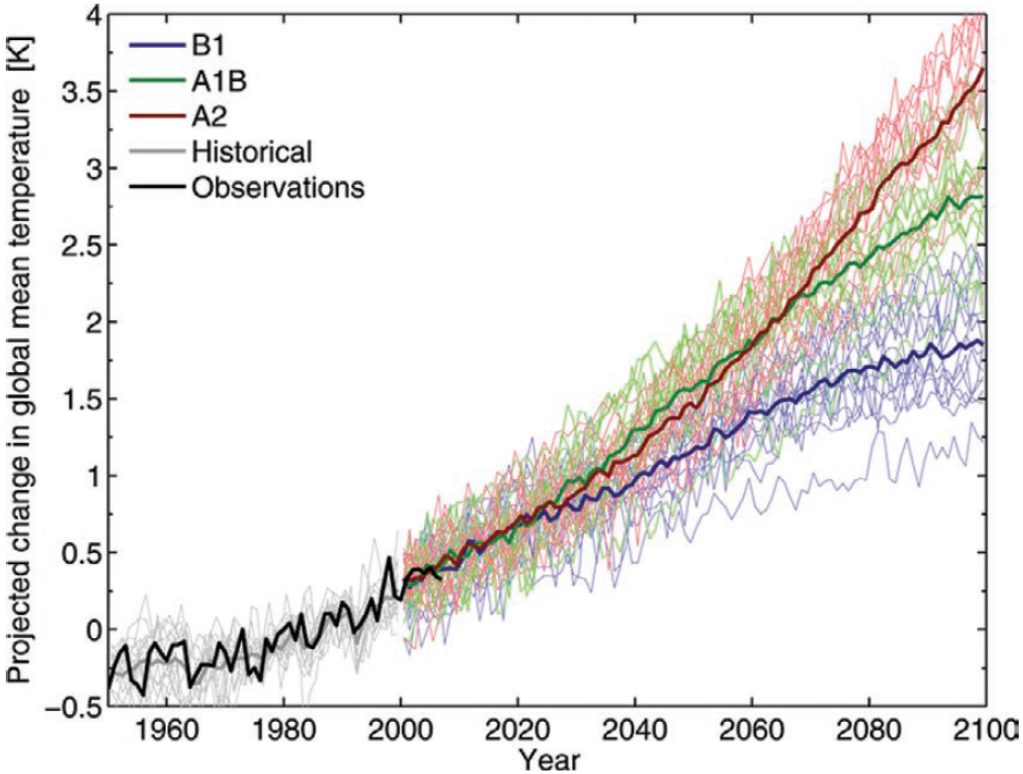
Hawkins, E., R. Sutton, 2009: The potential to narrow uncertainty in regional climate predictions. *Bull. Amer. Meteor. Soc.*, **90**, 1095 - 1107.

——, R. Sutton, 2011: The potential to narrow uncertainty in projections of regional precipitation change. *Clim Dyn.*, **37**, 407 - 418.

Kay, J.E., C. Deser, A. Phillips, A. Mai, et al., 2014: The Community Earth System Model (CESM) Large Ensemble Project: A Community Resource for Studying Climate Change in the Presence of Internal Climate Variability. *Submitted to BAMS.*

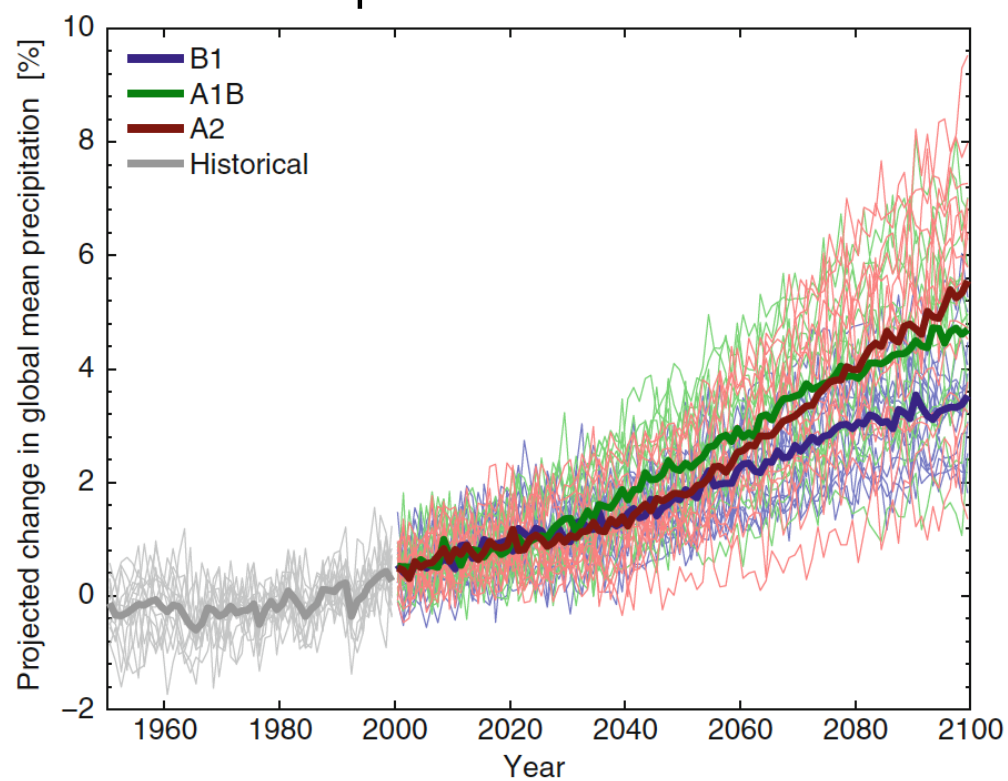
Supplemental Information

More goodies...

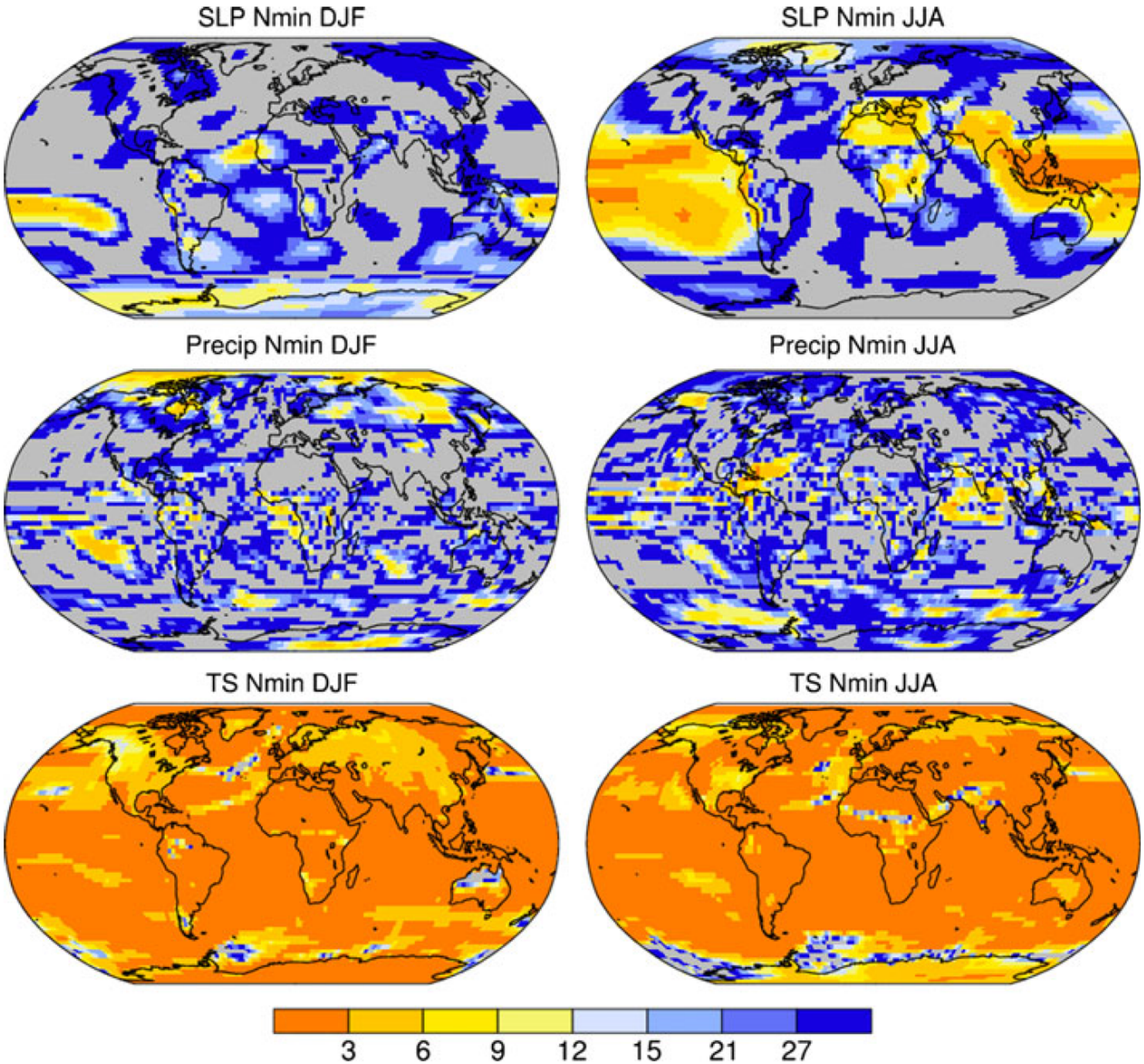


Temperature Trends

Precipitation Trends



Hawkins and Sutton [2009, 2011]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SLP Nmin JJA
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